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Prepared by:
Paul Appelqvist
Telephone:
0730 - 780 986
E-mail:
paul@akustikkonsulten.se
Client:
Norsk Vind AS
Reference:
John Amund Lund

Wind Farm Faurefjellet

Noise calculations

1 Background

Norsk Vind AS ("NV") have a permit (konsesjon) to build wind farm Faurefjellet in Bjerkreim municipality, Norway. Akustikkonsulten I Sverige AB ("Akustikkonsulten") has performed noise calculations, commissioned by NV, for the planned wind farm. The calculations are described in detail in Akusikkonsulten's report *10-19125 B01-B02 Noise calculation wind farm Faurefjellet 200429*. Calculations were performed both as a worst case as well as a yearly average (lokale wind forhold). The result showed that the noise limit L_{den}=45 dBA could be fulfilled at nearby dwellings.

One assumption in noise calculations with the calculation model Nord2000 is the temperature and other weather parameters as relative humidity and air pressure, of course there is an almost unlimited number of combinations that could be used. A standard approach for noise calculations, not only for wind turbine noise, is to use standardized parameters. This makes the calculations more consistent (reduces the risk that different consultants calculate different results) and makes it easier for an authority to review the calculations. Akustikkonsulten has done such reasonable assumptions in regards of the weather parameters as temperature, as described in the calculation report. It could be mentioned that the same assumptions are also common for calculation of noise from other community noise sources.

One should also note that the mentioned weather parameters, in comparison to other assumptions in noise calculations, have less influence on the calculated noise immission which is also mentioned in M-128/2014, *Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442/2016)*.

NV has now got comments from Norges vassdrags- og energidirektorat ("NVE") in regards of the assumed weather parameters, i.e. temperature parameters. The comment is specifically in regards of the effect on the calculated noise immission if a yearly average is used for the temperature parameters. NV has thus commissioned Akustikkonsulten to assess this effect using a yearly average of the weather parameters, which is presented in this Memo.

2 Akustikkonsulten – Technical expertise

Akustikkonsulten has leading expertise when it comes to performing calculation of wind turbine noise, both with the calculation model Nord2000 as well as other calculation models. Akustikkonsulten's consultants also have performed control measurements, of wind turbine noise, for around 100 wind farms and have been involved in several research projects throughout the last decade.

Akustikkonsulten are currently involved in a Swedish research project financed by the Swedish Energy Agency (Energimyndigheten) and Vindforsk, VindEL project *Sound from wind turbines - Development and validation of control methods*. Calculations performed by Akustikkonsulten has also been approved in many MTA for wind farms in Norway as well as in many permits for wind farms approved by the highest environmental court in Sweden, Mark- och miljööverdomstolen. Finally, Akustikkonsulten is one of a few consultants in the Nordic region that are accredited according to ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*, and the measurement standard for noise emission from wind turbines IEC 61400-11.

3 Calculation model

Calculation of noise immission should preferably be performed with an established and approved calculation model. For the performed calculations, the calculation model Nord2000 is used. Nord2000 is a commonly used calculation model, with good accuracy in complex terrain compared to most other commonly used calculation models. Nord2000 has also been validated specifically for Norwegian complex hilly terrain in DELTA report *"Validation of the Nord2000 propagation model for use on wind turbine noise"* (PSO-07 F&U project no. 7389). Hørsholm : DELTA, 2009. Nord2000 considers different aspects of sound propagation for example ground impedance (ground hardness), topography and wind direction. Nord2000 is also one of the recommended calculation models in the Norweigan guidelines on noise M-128/2014*, "Veileder til retningslinje for behandling av støy i arealplanlegging (T-1442/2016)"*. To Akustikkonsultens experience Nord2000 is also more conservative, with the same assumption, compared to the other two calculation models approved in M-128/2014, General Prediction Method (DAL 32) and ISO 9613-2.

4 Calculation conditions

The Nord2000 calculation model is a complex model that have many different parameters that influences the calculated noise levels. Different parameters, for example wind speed and ground impedance, will change the sound propagation and thus also the noise level at a receiver. Due to complexity of the calculation model, it is important that the person performing the calculations have knowledge about noise attenuation in general and the

calculation model in detail. In M-128/2014 many of the parameters are described, but recommended parameters are mostly not specified in detail. The parameters used in the calculations for wind farm Faurefjellet are based on Akustikkonsultens experience and the descriptions in M-128/2014 as well as recommendations by the software manufacturer SoundPlan. The aim is to perform calculations in accordance with the guidelines M-128/2014, representing "worst case støyberegninger" in chapter 9.8.2 in the guidelines.

All calculation conditions, except the yearly average of the weather parameters, are the same as described in the report *10-19125 B01-B02 Noise calculation wind farm Faurefjellet 200429*. If the yearly average is used for the temperature parameters it is also reasonable to use the yearly average for relative humidity and air pressure, i.e. site-specific weather parameters. The yearly average for the weather parameters has been provided by NV, based on long term measurements. The assumed parameters used in the calculations are given in Table 1.

Table 1 Yearly average of weather parameters used in calculations.

Parameters	Yearly average
Temperature	5,17 °C
Temperature gradient	-0,007917 K/m
Relative humidity	87,9 %
Air pressure	956 mbar

As mentioned, the other used calculation conditions are believed to represent "worst case støyberegninger" according to M-128/2014. Calculations for "lokale vindforhold" will always give lower noise levels compared to "worst case støyberegninger", as shown in *10-19125 B01-B02 Noise calculation wind farm Faurefjellet 200429*. This means that, most of the time during a year, the perceived noise level from wind farm Faurefjellet will be lower than the calculated noise levels for the worst case.

5 Calculation result

The calculation result is given for all calculation points, NSA:s, that have a calculated noise level of 40 dBA or higher for the worst case scenario, i.e. calculation case B01 in the calculation report. The calculation case B02, for a yearly average (lokale vindforhold), is not assessed. The result is also compared to the result from *10-19125 B01-B02 Noise calculation wind farm Faurefjellet 200429* for the same NSA and calculation case, i.e. case B01. The difference in calculated noise immission, between the two cases, are also presented with one decimal, although one should note that calculated noise levels should normally be presented as integer value.

In Table 2 the result is presented and in Figure 1 all NSA:s with a noise immission from ≥40 dBA is given, for indexing.

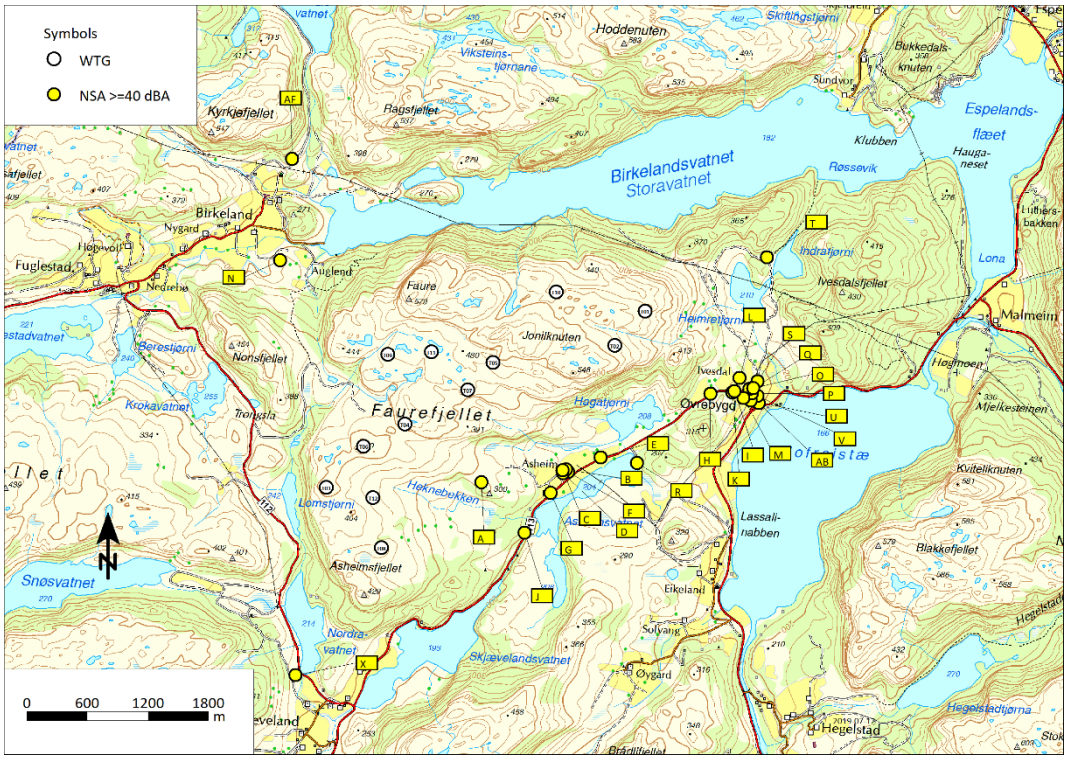

Figure 1 NSA:s with calculated noise immission ≥40 dBA for average weather parameters.

Table 2 Calculation result with standardized parameters (B01 200429) and yearly average parameters. For the difference standardized parameters give higher result for (+) and the opposite average parameters give higher result for (-). NSA above the noise limit 45 dBA are marked with red in the box.

NSA	Calculation height [m]	Calculation case B01 L_{den} [dBA]		
		Standardized parameters	Average parameters	Differecnce
A	1,5	48	49	-0,7
A	4	48	49	-0,6
AB	4	39	40	-0,2
AF	4	38	40	-1,5
B	1,5	45	45	-0,4
B	4	45	45	-0,5
C	1,5	45	45	-0,4
C	4	45	45	-0,4
D	1,5	45	45	-0,5
D	4	45	45	-0,5
E	1,5	44	44	-0,5
E	4	44	45	-0,6
F	1,5	44	45	-0,5
F	4	45	45	-0,4
G	1,5	44	44	-0,3
G	4	44	45	-0,6
H	1,5	41	42	-0,2
H	4	41	41	0,2

I	1,5	42	42	-0,4
I	4	42	42	-0,3
J	1,5	43	44	-1,0
J	4	43	44	-1,0
K	1,5	42	42	-0,1
K	4	42	42	-0,1
L	1,5	42	42	0,2
L	4	42	42	0,0
M	1,5	41	41	-0,8
M	4	41	42	-1,2
N	1,5	40	41	-0,5
N	4	41	41	-0,2
O	1,5	41	41	-0,4
O	4	41	41	-0,7
P	1,5	40	41	-0,3
P	4	41	41	-0,6
Q	1,5	41	41	-0,1
Q	4	41	42	-0,3
R	1,5	42	43	-0,5
R	4	43	43	-0,6
S	1,5	41	41	-0,2
S	4	41	41	0,2
T	1,5	40	41	-0,9
T	4	40	41	-1,0
U	1,5	40	40	-0,3
U	4	40	41	-0,7
V	1,5	40	40	-0,3
V	4	40	41	-0,5
X	1,5	39	40	-0,5
X	4	40	40	-0,4

As can be seen from the result the difference is roughly within ±1 dB which could be expected, and well within normal calculation uncertainties. This is also in line with what is mentioned in M-128/2014 for these weather parameters. In regards of NSA A the property owner have an agreement with Norsk Vind AS and the NSA should not be considered in regards of the noise limit L_{den}=45 dBA.

In Table 3 the calculation result for 4 m height above ground is summarized and compared to the relevant noise zones (støysoner) in M-128/2014.

Table 3 Calculation result compared to noise zones (støysoner) in M-128/2014.

Noise zone	Number of residential dwellings in noise zones for B01	
	Standardized parameters	Average parameters
L_{den} >55 dBA	0	0
L_{den} >45-55 dBA	1	1
L_{den} >40-45 dBA	24	24

As can be seen in Table 3 it is the same number of NSA:s (dwellings) within the green zone using both setup of parameters. Although it shall be noted that not all NSA:s in the green zone are the same for the two cases, as some NSA:s in the green zone for standardized parameters are below 40 dBA with average parameters and vice versa. This is a good example of why it is not given that changing one parameter will result in either higher or lower noise levels. The Nord2000 calculation model is as mentioned complex and so is the real effects of different weathers impact on noise attenuation over large distances.

If a future control of noise would show that some residential dwellings are in the yellow or red noise zone, there are also noise settings with lower noise emission (Støymodus for reduksjon av støy) available down to 98,0 dBA. This means that all wind turbines in wind farm Faurefjellet have a possibility for noise reducing measures (Avbøtende tiltak) of 6,9 dB for the used wind turbine type Vestas V150-5,6 MW.

6 Summary

The noise calculations for wind farm Faurefjellet, presented in this Memo for a yearly average of weather parameters as well as the calculations presented in *10-19125 B01-B02 Noise calculation wind farm Faurefjellet 200429,* show that the wind farm can fulfil the noise limit 45 dBA, for the used wind turbine type Vestas V150-5,6 MW.

The calculations are based on conservative assumptions representing "worst case støyberegninger", as described in M-128/2014. This means that most of the time during a year, the noise level will be lower than the calculated noise levels.

Akustikkonsulten wants to point out that there are an infinite amount of possible combination of calculation settings and different settings will give slightly different results, both higher and lower, often both at the same time depending on distances, terrain effects etc. In most realistic cases the differences between different settings are small and has no impact on the perceived noise level. The priority should be to make correct calculations that represents the most probable result (sannsynlig resultat). That requires experience not only from noise calculations, but also from noise measurements and understanding uncertainties as well as the human perception of noise. For example, a difference of 1 dB cannot be perceived by a normal hearing person under normal conditions, which is one reason why most studies on noise disturbances are made in intervals of 5 dB.

Noise limits are also often set based on studies of perceived annoyance at certain noise levels. The noise levels in those studies are often calculated under normal conditions. If drastically changing the calculation parameters, or other assumptions, from those normal conditions the results might not correlate with the conditions under which the noise limits were once set and therefore not be a valid comparison.

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Prepared by	Quality reviewer
Paul Appelqvist Senior Consultant Acoustics	Jens Fredriksson Senior Consultant Acoustics